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Paul O'Neal

For approximately one hundred years, every new Neandertal find has met with discussion, if not controversy. One of the latest controversies has concerned the gestation period required for Neandertals and the significance of the morphological irregularities of the Neandertal pelvis. As with almost every aspect of Neandertal, the debate has divided into two camps which have distinct viewpoints about the place of Neandertal in the evolution of the human species.

These two camps are best described as the "single origin or replacement model" and the "multiregional model". In the single origin model, it is assumed that Neandertal was replaced by expanding modern *Homo Sapiens* coming out of Africa, with Neandertal having little, if any, contribution to modern *Homo Sapiens*. In the multiregional model, *Homo Sapiens* evolved in different regions and either through interbreeding or direct evolution, Neandertal is related to modern European populations.

It can be seen that both of these camps have agendas regarding every aspect of Neandertal. The question of obstetrics and pelvic morphology has become the newest battleground for these beliefs. The replacement model proponents are interested in showing that for various reasons the Neandertal were less evolutionarily fit, needing, for example, a twelve month gestation period, while the multiregionalists want to show that there was little difference between Neandertals and modern *Homo Sapiens*. If there is no need for a reproductive change from Neandertal to modern humans, this is a small victory for multiregionalists (Greene, 1988:609).

As is usual in these cases, the evidence is sufficiently equivocal to allow for both sides to claim that the fossil remains favor their point of view. I want to spend some time now reviewing and discussing the opinions that have already been expressed on this topic.

The undisputed evidence is that the Neandertal pelvis shows a distinct morphology, especially in respect to an exceptionally long superior pubic ramus. The question is, what does this mean?

The strange morphology of Neandertal pubic bones was noticed when the first specimens were found, but the problem was that all of the original samples found were partial (Stewart, 1960:1437). Although the difference in the pubic bone was always noted, there was no attempt to attach a significance to this morphology until 1976 (Trinkaus).

At this time Trinkaus felt that, even though no complete pelvises, or even complete innominates, had been found, that it was possible "to determine their morphological configurations" (Trinkaus, 1976:95). His paper again notes the elongated superior pubic ramus but mostly discusses relative pubic robusticity, a factor that he considered important, and one that was certainly notable (Trinkaus, 1976:96).

In 1984 Trinkaus again addressed the question. This time he postulated that since bipedalism had already been reached before the advent of modern *Homo sapiens*, any change in the morphology of the pelvis had to be due to a change in reproductive pattern. He also stated that since Neandertal had been "replaced" by modern humans, modern human morphology must have had a selective advantage.

He then proceeded to state that since the pubic bone is relatively longer and there is no other change in the pelvis, the pelvic opening must be larger than that found in modern humans (510). The problem was, that there still was no complete pelvis to study.

All of this led to his proposal that the gestational length for Neandertal was three months longer than the gestational length for modern humans. This would explain the larger pelvic size that he had suggested, because during the three months the Neandertal child would have grown larger and would have needed the larger pelvis to accommodate the extra growth (510).

This also leads him to state that since modern humans had shorter gestation times, and since there was little difference in brain size and body mass between Neandertal and their modern successors, there must have been improved obstetrical techniques and perinatal care for modern humans (510). There would have been a need for all types of social and cultural changes to accommodate this three month premature infant, which Trinkaus considers a selective advantage. This is difficult to understand. It would seem to me that until the better obstetrical care was developed, the decrease in gestation time and decrease in the size of the birth canal would have led to an almost one hundred per cent infant mortality rate, which would not have been too advantageous. Trinkaus uses a teleological argument when he suggests that since modern humans did replace Neandertal, the morphological changes must have conferred a selective advantage.

In 1985 Francis Ivanhoe entered the fray, but immediately headed out in a different direction. He considers that the enlarged pelvis shows sign of acromegaly (Ivanhoe, 1985:526), a disease of the pituitary gland that leads to enlargement of the extremities (Funk and Wagnalls, 1974).

Trinkaus was not impressed with this line of argumentation, lamenting that he "was hoping that the resultant discussion would be well informed" (Trinkaus, 1985:527). He completely dismisses Ivanhoe's claims, stating that Ivanhoe misinterprets the fossil record and is confused regarding acromegaly and gigantism. He states that Ivanhoe's comments "merely confuse the issue" (528). Trinkaus (1976:102) noted early in the debate that the lengthened pubic bone was not likely related to hypertrophy, eliminating that as a possible theory.

At the same time, Trinkaus took the opportunity to restate part of his case. In his opinion, human gestation should be twelve months, given the time required for human brain development when compared to our non-human hominoid relatives. He believed that at the time of the Neandertal/modern changeover that this time decreased. He also stated that this was due to cultural and social changes, while at the same time being responsible for those same changes (527).

Trinkaus believed that there were specific advantages that would cause a shorter gestation time to be selected. The first of

these was the possibility of a reduction in birth spacing, allowing for an increase in population growth (Trinkaus, 1984:512), but Anderson (1991:332) contended that suckling inhibits ovulation far more powerfully than pregnancy length, therefore, there would not likely be any increase in population. Also, lactation is less energy efficient than placental exchange.

Karen Rosenberg enters the discussion with a new premise that states that Neandertal males seem to have larger pubic lengths that females (1986:257). Her hypothesis is that because of increased sexual dimorphism among Neandertal, males could have had larger pubes when selection was acting only on efficiency in bipedalism for men.

Rosenberg later (1987:222) suggests that elongated superior pubic rami are suggested in cases of populations that have heavy babies with large heads relative to their stature. In other words, she agrees that Neandertal neonates had larger head sizes, but does not necessarily correlate this to increase in gestational length. She also feels that the large Neandertal neonates were derived from their large mothers (Garn and Pesick, 1982:667).

A breakthrough in this issue came with the release in 1987 of a paper by Rak and Arensburg detailing the discovery of a complete Neandertal Pelvis. This male pelvis immediately indicated that much of the previous debate was based on a critical wrong assumption. While it was true that the acetabulo-symphyseal length was in fact longer in Neandertal, it now appeared that this had no bearing on the pelvic diameter (Rak and Arensburg, 1987:227-231).

Rak and Arensburg suggest, in fact, that there is little difference between Neandertal and modern humans in regards to the general size of the pelvis, while at the same time exhibiting interesting morphological variations (227). The most pertinent of these also explains the excessive length of the pubic bone. The innominate bone is more externally rotated than that of a modern human's, resulting in a more laterally oriented acetabulum. This is the cause of the extended superior pubic ramus. (Rak and Arensburg, 1987:229). Even Trinkaus had to concede that the acetabulo-symphyseal length of the superior pubic ramus had nothing to do with predicting the size of the pelvic aperture (Trinkaus, 1988:611).

Their final conclusions, however, do not necessarily follow the available information. They state that if there are differences found in the Neandertal pelvis, they must be attributed to the requirements of locomotion and posture. While it is clear that obstetrical requirements are not the only cause for the unusual morphology, I do not think that they can be dismissed as irrelevant (Rak and Arensburg, 1987:230). The (female) Homo pelvis has been involved in childbirth since its inception, and has been involved in the process of bipedalism for a somewhat lesser time (Emmons, 1913:35).

There are those who would insist that the width of the pelvis is not pertinent to obstetrics in any case. Australopithecines already had a pelvis that was wider than necessary for their infants, who had small heads, and they had gestation times similar to modern humans (Anderson, 1989:328). They also experienced different rotation during birth than either humans or primates (White, personal communication).

It seems clear that at that time the selective force involved with pelvic morphology was bipedalism, and that sexual dimorphism developed later (Arsuaga and Carretero, 1994:242). In fact, it is clear that it is the anteroposterior diameter that causes problems, if any occur; therefore, the transverse diameter would not necessarily select for childbirth anyway. The pelvis is already wider than it needs to be (Abitbol, 1987:80).

The current state of the argument seems to be an agreement that Neandertal and moderns were actually quite similar in pelvic opening size, with Neandertal being slightly larger in the transverse. Rosenberg has recently gone so far as to say that Neandertal is actually smaller in the pelvic outlet diameter, and that if Neandertal females showed similar dimorphism to moderns "it is unlikely that they would have been capable of giving birth to a large brained infant" (Rosenberg, 1992:115).

OBSTETRICAL REQUIREMENTS

We first need to get an understanding of the obstetrical requirements of the female pelvis. Obviously there needs to be enough space for the child's head to pass. But there are many variables that need to be taken into account.

Cephalic molding takes place to allow the infant's cranium to change shape during delivery. This is possible because of the open sutures in the fetal skull. Molding can safely reduce the biparietal diameter by 4mm., but actually 6-7 mm. is available if the pelvis is wide transversely, because then the molding will only have to take place in one direction (Donald, 1979:519).

Much has already been written on this topic and likely more will be written in the future. I wanted to review the literature, but also to get a limited hands-on perspective. I decided to begin by examining the Kebara Pelvis. I first checked and compared the measurements in the Rak and Arensburg article against the cast in the lab. Having confirmed these measurements, I then made the same measurements on a selection of modern innominate bones for purposes of comparison. The results of these measurements can be seen in Table 1.

I should at this point note that there are several factors that need to be taken into account in assessing the figures here and elsewhere in this paper. One involves the simple process of measuring skeletal material. In all cases I was as careful as possible when making measurements, but even that will not compensate for differences in technique or interpretation. Another consideration is that the sample is extremely small. Five modern samples and one Neandertal would allow one anomalous specimen to have too much of an impact on the final averaged numbers.

As can be seen in this chart, there is a wide diversity even among modern humans, and in some studies there had been a range in the transverse diameter of between 103 mm. and 147 mm., with an average of 129.5 mm. (Emmons, 1913:38). In other studies, the variation has been even larger, with large variations in the subpubic angle as well. This angle shows a variation of between 76 and 120 degrees (Ince and Young, 1940:147), while the Kebara pelvis shows an angle of 110 degrees, which is noted as extremely large Rak and Arensburg, 1987:228). It seems to me that (even given these large variations) the Neandertal is generally speaking larger, especially in the transverse diameter. In fact, in this measurement, the male Kebara is larger than the mean of almost all modern human populations (Rosenberg 1988:613). This is to be expected given the unusual morphology that is immediately apparent. It is also accepted that Neandertal sacra are virtually identical in size to ones found in modern humans

(Trinkaus 1984:509). Sacral width, therefore, cannot be used to explain this anomaly. The one consideration that needs to be taken into account with regards to the sacra is that it is considered one of the bones with the largest degree of variability in the human (De Souza, 1913:489). The width of the sacrum is also largely responsible for the transverse diameter of the pelvis (Caldwell and Moloy, 1933:485).

When looking at the figures, it seems that the Neandertal is certainly within a reasonable range of some of the modern innominates. One major consideration, though, is that the male Neandertal is closest to the modern female. In any examination of fossil pelvises, sexual dimorphism is extremely important. Given a limited sample, it becomes even more important to determine the effect of sexual dimorphism on any given fossil (Rosenberg, 1994, 173). This leads me to consider one of Karen Rosenberg's theories. She asserts that in Neandertal, a unique sexual dimorphism occurs that is not seen anywhere else in the fossil, or even the primate, record. She contends that Neandertal males had longer pubes than Neandertal females. Given my figures for Kebara, compared to modern innominates, this would then make the female Neandertal almost exactly the same size as the modern female.

This, of course, would end any speculation on twelve month gestations and acromegaly, but where is the evidence for this unusual dimorphism? The fossil evidence is incredibly sketchy to make such a statement. There is only one complete male pelvis and no complete females, Rosenberg cites evidence among modern humans that in populations with high degrees of body-size sexual dimorphism, pubic bone sexual dimorphism may be reversed. (Rosenberg, 1988:606).

This certainly goes against what is considered normal for modern human populations. The average sizes of the bones, the ilium and the ischium for example, are larger in males than in females due to the larger size of the males. But the pelvic inlet is larger in women, partially due to a larger or more open sciatic notch. Segebarth-Orban (1980:607) notes that "the pelvic cavity is the only part of the skeleton we know of which is larger among women than among men". The same author notes later that,

> "the female pelvis seems to have been fashioned by the selective forces, which in the present case are in close relationship to the function of reproduction" (1980:607).

To demonstrate her theory concerning unusual body size sexual dimorphism in Neandertal population, Rosenberg uses, as a male sample, La Ferrassie, which, by her own admission, is very large, even for a Neandertal (Rosenberg, 1988:606). I think that this is an unacceptably small sample for making these kinds of predictions, and basing assumptions on evidence that is skewed in favor of your hypothesis can lead to false conclusions. Anderson (1991:333) admits that the uniqueness of Neandertal pelvic sexual dimorphism "may be the result of error in such a small sample of pelvises".

I have been surprised to find that Rosenberg (1986) is now commonly cited in the literature (Aiello and Dean, 1990:456; Rak and Arensburg, 1987:230) as having successfully demonstrated the Neandertal's unusual pubic sexual dimorphism. In fact, it has not been seriously questioned in any literature that I have seen, except in the case of Anderson already noted.

The actual sex of any Neandertal specimen is apparently in some doubt, at least with some people. Usually the pelvis is one of the main tools in determining the sex in skeletal remains. The problem with Neandertal exists because there is only one complete pelvis available for comparison, and it shows marked morphological peculiarities when compared to modern humans. Baskerville (1989:486) suggests that the sex is not accurately known for any Neandertal individual.

I think that this is one of those cases. The fossil evidence for this extreme form of body size sexual dimorphism does not exist. In fact, Wolpoff (1980:289) reports that average female height was ninety-four per cent of the male average height in Neandertals, compared to a modern average of between ninety-two and ninety-five per cent. His note on this topic is: "thus the degree of dimorphism in body size is within the living human range and reduced from earlier samples" (Wolpoff, 1980:289).

This leads me to hypothesize that possibly Neandertal had a similar pattern of sexual dimorphism as modern human. If this was the case, the female obstetrical pelvis, in other words the birth canal, would have been larger than the male Kebara specimen. It would then follow that a Neandertal female pelvis would be larger than an average modern human pelvis. If this is indeed the case, are we left with twelve month gestation as the only reasonable theory?

It seems to me that there is another possibility that needs to be tested. It would seem reasonable that if the Neandertal obstetrical pelvis actually was larger, the reason would have been that the Neandertal neonate was larger too. But I do not think it follows as readily that it took twelve months to produce that infant. I think that there may have been other factors to consider.

NEONATE CRANIAL DIMENSIONS

It seems to me that after considering the pelvis, the most obvious morphological differences between Neandertal and ourselves are in the size and shape of the cranium. If a Neandertal neonate had a larger head at birth, this would make a larger pelvic cavity not only reasonable but necessary. Unfortunately, there are no fossil remains for a Neandertal neonate that we can use to test this theory directly. In fact, there are only five Neandertal individuals in the fossil record between the age of birth and nine months. Among these, not even one cranium or even cranial bone can be reconstructed (Tiller, 1994:195).

One of the few pieces of evidence that does exist for Neandertal children is the Devil's Tower child. This child was originally aged as five years based on cranial size and development, but this has recently been changed to three years. The change has been effected through the use of dental development analysis, which indicated the three year old age. What this has led the investigators to conclude is that Neandertal "achieved rapid brain growth before birth and that this resulted in the need for a larger pelvic outlet (Dean et al., 1986:308).

However, this still leaves us without the actual size of the Neandertal neonate's head. There is a way that can give us some measurement to test this theory, but there are some problems that should be recognized first. The assumption that has to be used is that Neandertal and modern human cranial development was similar from birth to maturity. I realize that this is a large assumption, but I feel that it is still worthwhile

to consider this evidence. One other consideration has to be the small sample that I am using. I understand that I am using too small a sample to get statistically reliable results, but at this point I consider this examination preliminary and, as such, I am just testing to see if the hypothesis is reasonable.

Measurements were then taken from five modern human crania. These measurements were used to obtain averages for each dimension measured. The results are in Table 2.

Sexing of the crania was unimportant because we are dealing with birth size and, of course, infants of both sexes have to pass through the birth canal. These averages were then taken and plotted against the measurements obtained for modern neonates. This gave me a ratio of mature to neonate. This same ratio was then applied to the measurements obtained from the Neandertal material to obtain measurements for the Neandertal neonate. These figures are shown in Table 3.

The average increase in size of the Neandertal neonate is shown to be fifteen per cent, which is a small but significant figure. I would suggest that this explains the apparently larger pelvic inlet among Neandertals. Anderson (1991:335) believes that "the larger the head the larger the pelvis, and Neandertal heads were considerably larger than those of recent humans". In other words, Neandertals were born larger than modern humans and stayed larger (Smith, 1991:228). In our times, in cases of large neonates, it is suggested that caesarean section be used. "Exceptions may be made where the pelvis is unusually large" (Quilligan and Zuspan, 1982:387). Before caesareans, a large pelvis could have been a life saver for both the mother and child.

Not only was the head of the Neandertal neonate larger. Many believe that Neandertal was generally more robust and bulky that modern humans (Brace, 1988:607). This could lead to a new set of problems that I won't cover in depth. Dystocia, or difficult delivery, can occur when either the pelvis is too small or the child is macrosomic. But not just the head is involved; wide shoulders and even a barrel chest can result in dystocia (O'Leary, 1992:11). In fact, if the chest measurements of a neonate are as little as fourteen millimeters larger than the biparietal measurements, then the chance for shoulder dystocia is significantly increased (Trevethan, 1988a:678). Both of these features are considered part of the typical morphology of Neandertals (Trinkaus, 1983:208,220). In this case, even if the head was not considerably larger than modern humans, the general larger size of the child would have required the larger pelvis.

Trevethan (1988b:611) also finds it interesting to discover the considerably larger obturator foramen in Neandertal. Often, during childbirth, the anterior shoulder is accommodated by the obturator foramen during the delivery of the posterior shoulder. She suggests that possibly the wide shoulder of Neandertals selected for the wide transverse diameter of the pelvis and the larger obturator foramen.

There are other theories with at least some evidence in their favor, and there is no reason why Neandertal pelvic morphology could not have been partly influenced by a combination of them. One theory fits closely to other facts we know about Neandertals is the cold adaptation hypothesis. Modern humans that are cold-adapted, such as Innuit, have absolutely and relatively larger pelvises than other modern humans. This has to do with maintaining short stocky bodies to preserve heat. This is in accord with what we know of the climate at the time the Neandertals existed (Anderson, 1991:334).

Another suggestion that involves cold weather, is the known correlation between low temperatures and large birth-weight infants. In the case of Neandertal, it is possible that selection was working to produce large infants able to deal with cold. It's also interesting to consider that modern humans seem to have had the technology to protect themselves, and so it is possible that they did not need the larger infants, or the larger pelvis that was necessary to deliver them (Smith, 1981:228-229).

Another theory that deals with overall adaptation is the locomotion hypothesis. If obstetrics is not the defining variable in the morphology of the pelvis, locomotion is a very strong second candidate. The importance of the pelvis to bipedalism can not be overlooked, and given the similarity of the Neandertal and Australopithecus' pelvises, it is apparent that this adaptation is indeed ancient (Anderson, 1991:334).

The obstetrical requirements of the pelvis have seemed in some cases to obscure some other very important functions. One of its most important functions is acting as an anchor, transferring the stress between the upper body and the legs caused by upright locomotion (Tappen, 1988:610).

On a slightly different topic, with the discovery of modern-like pelvises dating considerably earlier than some Neandertals, it is becoming clear that Neandertal cannot be ancestral to modern humans. This would seem to support the replacement theory. Neandertal could still have contributed genetically to moderns through interbreeding, but even that is questioned because of the pelvic morphology and its significance. Neandertal would have been at a distinct disadvantage because if Neandertal children actually were considerably larger than moderns, a combination of Neandertal male and modern female would have likely led to the death of the mother and child because of the mother's relatively small pelvis. This is a fairly drastic form of selection. The combination of Neandertal women and modern man would have had a higher likelihood of success, but that still would limit the contribution possible by Neandertal to our genetic pool.

Even if the dates for these pre-Neandertal moderns are off by a few thousand years, there doesn't seem to be enough time for the Neandertal pelvic morphology to have changed to modern. It would seem at the very best, Neandertal could have contributed some genetic material.

What happened, then to this distinct pelvic morphology, the extended superior pubic ramus? With a history apparently extending back to australopithecine, why was it suddenly selected against when compared to the modern morphology? Just as we are not sure why it was selected for in the first place, we can only hypothesize concerning its demise. It could have been a result of recent changes in robusticity, overall body shape due to climatic changes or some change in the efficiency of locomotion (Rosenberg, 1989:487)

CONCLUSION

Much of the evidence presented in this paper is estimated or extrapolated, but I feel that the hypothesis presented here is suggested by the facts, and therefore is worthy of consideration.

The twelve month gestation hypothesis is, I believe, thoroughly discredited. Connie Anderson (1989:332) writes the epitaph: "The gestation hypothesis is most unlikely to be

correct, since all the premises on which it is based are at least questionable, if not clearly wrong".

But we are far from knowing what the exact cause or combination of causes are. What we need is more Neandertal material to examine. In particular, I would want at least one complete female pelvis represented, plus more Neandertal infants and children, to more properly fill out our incomplete picture.

TABLE 1
Innominate Bone Measurements
(all measurements in millimeters)

	Modern Females			Modern Males		Neandertal
	A	**B**	**C**	**D**	**E**	**F**[1]
Sacrum[2]	106	110	110	101	104	118
Pelvic Inlet[3]	103	118	104	86	94	117
Transverse Diameter[4]	110	120	120	110	110	138
Pelvic Outlet[5]	86	100	112	101	86	90
Acetabulo-Symphyseal Length[6]	58	61	66	60	61	88
Breadth of Innominate[7]	135	149	143	132	146	156
Greater Sciatic Notch[8]	46	48	42	38	38	41

TABLE 2[9]

	11	8	7	5	1	Averages
Occipital-frontal[10]	178[11]	168	163	183	168	172
Biparietal[12]	121	132	118	140	127	127.6
Bitemporal[13]	106	100	95	118	102	104.2
Verticomental[14]	220	218	200	225	212	215

TABLE 3

	Modern		Neandertal		
	Adult[15]	**Neonate**[16]	**Adult**[17]	**Neonate**[18]	**Difference**[19]
Occipital-frontal	172	110	203.5[20]	130.2	118%
Biparietal	127.6	95	147.5[20]	109.8	116%
Bitemporal	104.2	80	110[20]	84.5	106%
Verticomental	215	135	257[21]	161.4	120%

[1]Measurement taken from cast of Kebara fossil pelvis.

[2]Sacral measurements are taken at the maximum breadth of first sacral vertebra across alae.

[3]Measured from the middle of the sacral promontory to the postieror superior pubic symphysis.

[4]Transverse diameter of pelvis is the widest point between iliopectineal lines.

[5]Pelvic outlet is measured from the anterior inferior pelvic symphysis to the tip of the sacrum.

[6]Acetabulo-symphyseal length is the measurement of the superior pubic ramus from the nearest point of the acetabulum to the pubic symphysis

[7]Measurement between the anterior-superior iliac spine to the posterior-superior iliac spine.

[8]Measurement of opening of Greater Sciatic Notch.

[9]All numbers are identification numbers assigned by the University of Western Ontario Anthropology department

[10]The Occipitofrontal measurement is taken from the external occipital protuberance to the glabella.

[11]Measurements are in millimeters

[12]Biparietal measurements is measured between the parietal bosses and is the widest transverse measurement.

[13]Measured between the lateral sides of the temporal bones.

[14]Measurement from gnathion to opisthocranion.

[15]Averages taken from Table 2.

[16]Measurements from Oxorn, 1986:46.

[17]Material for measurement from the collection of The University of Western Ontario's Anthropology department.

[18]This measurement is arrived at using the formula, Neandertal adult measurement divided by Modern adult measurement times Modern neonate measurement.

[19]This is the difference between the Neandertal and modern neonates, shown as a percentage of the modern measurements.

[20]Average taken from Amud 1 and Calotte Skulls.

[21]Measurement taken from Amud 1 Skull.

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